The Paleontograph

A newsletter for those interested in all aspects of Paleontology
Volume 10 Issue 3 December, 2021

From Your Editor

Welcome to our year end edition. I hope this issue finds you healthy and safe. While I've been very busy with my personal and fossil business life Bob has been writing away. I should have put out an issue, months back but things were just too hectic this year. Covid jumbled up my schedule and also caused a very large increase in business. I suppose it's pent up demand or people saved a lot of money while staying home. In any case, it's made my life a bit crazy.

To paraphrase Al Pacino in one of his movies, "Just when I thought I was out, they pulled me back in". That seems be sum the pandemic up pretty well. I hope we can get thru this one of these years but that will probably not happen.

Well, enough of that. I want to wish you all a safe and healthy holiday season.

PS. If any of you come to Tucson, I will be at the Fossil & Mineral Alley Show at the Days Inn , Rm 140. Stop in and say Hi.

The Paleontograph was created in 2012 to continue what was originally the newsletter of The New Jersey Paleontological Society. The Paleontograph publishes articles, book reviews, personal accounts, and anything else that relates to Paleontology and fossils. Feel free to submit both technical and non-technical work. We try to appeal to a wide range of people interested in fossils. Articles about localities, specific types of fossils, fossil preparation, shows or events, museum displays, field trips, websites are all welcome.

This newsletter is meant to be one, by and for the readers. Issues will come out when there is enough content to fill an issue. I encourage all to submit contributions. It will be interesting, informative and fun to read. It can become whatever the readers and contributors want it to be, so it will be a work in progress. TC, January 2012

Edited by Tom Caggiano and distributed at no charge

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Fantastic Fossils –A Review

Bob Sheridan --March 28, 2020

The author of this book, Donald Prothero, is a professor of geological sciences of California State Polytechnic University and also a research associate in vertebrate paleontology at the National History Museum of Los Angeles County. He has written about twenty popular books on geological, paleontological, or general science topics, and I have reviewed several of them for the Paleontograph. At this point, I can pretty much recommend everything he writes, since he has a very good style and his information seems very up to date. That is why I read his latest book "Fantastic Fossils."

The Chapters are:
1. Fantastic Fossils
2. How are Fossils Formed
3. What Kind of Rocks Yield Fossils
4. Where Do You Find Fossils
5. Dating Fossils
6. Collecting Fossils (Badlands)
7. Collecting Fossils (Beaches)
8. Collecting Fossils (Quarries and Roadcuts)
9. The Crucial Step (Collecting Data)
10. What's in a Name
11. Phylum Porifera
12. Phylum Cnidaria
13. Phylum Brachiopoda
14. Phylum Bryozoa
15. Phylum Arthropoda
16. Phylum Mollusca
17. Phylum Echinodermata
18. Phylum Hemichordata
19. Phylum Chordata
20. Paleobotany

Chapters 1-5 (on how fossils are formed, found, and collected), and in some part Chapter 10 (which is on how fossil genera and species are named), are pretty familiar territory for those of us who follow paleontology as a hobby. However, they contain very useful summaries for those who are new to the topic.

Chapters 6-9 have some advice for amateur collectors, but most of this is on the level of "ask permission" and "be safe." Remember, this is not a book about sites where anybody can collect. For that you need another book like Albert Dikas's "101 American Fossil Sites you Gotta See".

Chapters 11-20 talk about specific groups of fossil organisms. You can see that invertebrate fossils (which are by far more common) get about equal emphasis as the more glamorous (and rare) fossils like dinosaurs or prehistoric mammals, but there are plenty of other books for that, including some by Prothero. However, these are the chapters I found most useful. For example, Chapter 15 contains a very good summary of the anatomy of trilobites and a good summary of the classes of trilobites. Similarly, Chapter 13 and the anatomy and classes of brachiopods, and Chapter 16 on the anatomy and classes of ammonites.

This book is densely illustrated, mostly with black and white photographs of fossils and clear scientific diagrams. There is a small central section of color plates.

I can recommend "Fantastic Fossils" as a very good general overview. It would be perfect for someone just starting to be interested in fossils.

Sources:
Prothero, D.R.
"Fantastic Fossils: A Guide to Finding and Identifying Prehistoric Life."
Columbia University Press, New York, 2020, 323 pages ($35)

Asteriornis

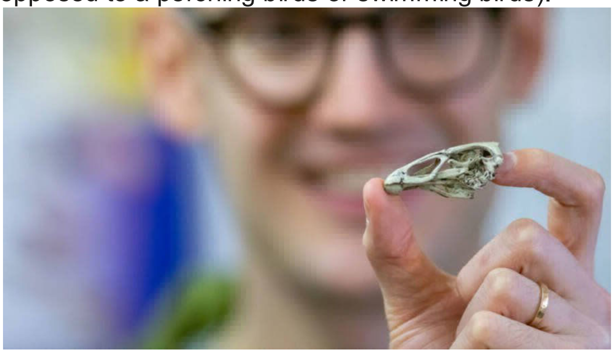
Bob Sheridan March 22, 2020

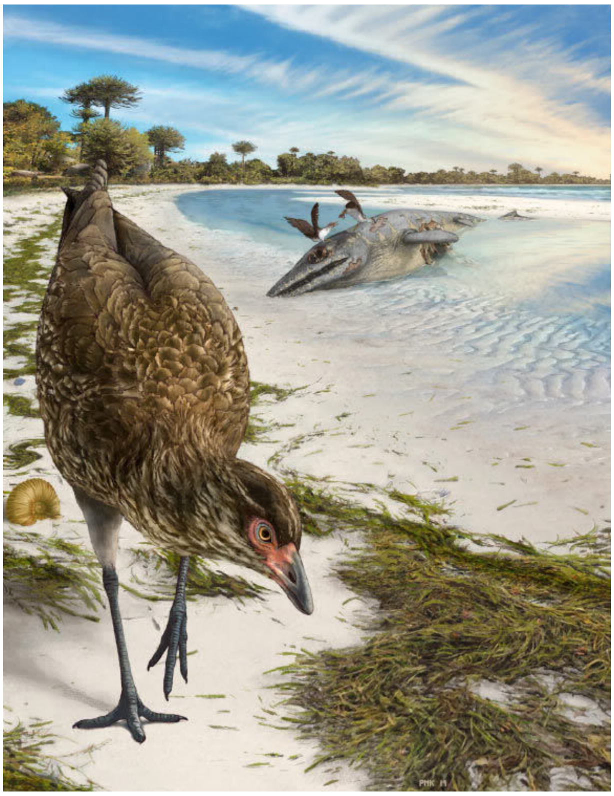
Just as I was finishing the previous story about the isolated skull of an unusual Mesozoic bird Oculudentavis, I came across something similar in a different article. Field et. al. (2020) report a fossil bird from Latest Cretaceous limestone in Holland (~68 Myr). (In fact the Latest Cretaceous is named for the Dutch town of Maastrich near which these formations occur.) The rock containing the specimen showed fragments of limb bones at the surface but the skull was discovered and studied only by CT-scanning. This is a case where, had investigators started chipping away at the exposed bones, the skull probably would have been damaged.

As well as an entire skull, there are partial elements of the leg and arm. The authors name this animal *Asteriornis maastrichtensis*. (Asteria is the Greek goddess of falling stars who, in one story, turned herself into a quail.) In life, Asteriornis would be about the size of a seagull.

Cont'd

The most interesting thing about the skull of Asteriornis is how modern it looks despite being from the Mesozoic. The authors feel Asteriornis represents a very primitive galloanseran, the group of birds that contain chickens, turkeys, quails, ducks, geese, and swans. The bones at the back and top of the skull resemble those of modern ducks whereas the front more resembles that of chickens and turkeys. I have a goose skull in my cabinet, and to me the Asteriornis skull resembles that of a goose except for being shorter from front to back. The upper beak of Asteriornis is flat like that of a goose, without the downward hook one sees in chickens. The leg bones of Asteriornis are rather long compared to the length of the skull, so Asteriornis was probably a shore-dwelling wading bird (as opposed to a perching birds or swimming birds).





Phylogenetic analysis places Asteriornis well within the group of crown birds, diverging sometime after the paleognathae (the group of modern birds that includes the ratites), but before galliforms (chicken-like birds) split from anseriforms (duck-like birds). "Crown birds" is the term given to the birds that have living descendants.

It has long been a matter of discussion whether the current groups of crown birds diverged before or after the K-T extinction. Two lines of evidence, molecular comparisons among living birds and geological dates for fossil birds, do not seem to agree. Also, while fossils of Early Cretaceous birds are very common in China, there are few fossil birds from the Late Cretaceous. The fact that Asteriornis comes from just before the K-T extinction implies that at least one group of crown birds existed in the Mesozoic and, further, that they lived along side more primitive birds. For example, an Ichthyornis-like bird is also found in the same formation. Ichthyornis is a toothed diving bird, which is more commonly known from North America. Also, it has been suggested that modern birds originated in the Southern Hemisphere because some Mesozoic crown birds have been found in Antarctica. However, the fact that Asteriornis is a crown bird found in North America, makes that claim less certain.

Sources:

Field, D.J; Benito, J.; Chen, A.; Jagt, J.W.M.; Ksepka, D.T.
"Late Cretaceous neornithine from Europe illuminates the origin of crownbirds."
Nature 2020, 579, 397-401.

Padian, K.
"Poultry through time."
Nature, 2020, 579, 351-352.

Vogel, G.
"Oldest fossil of modern birds is a 'turducken'.
Science 2020, 367, pg. 1290.

Sinomacrops

Bob Sheridan April 11, 2021

Pterosaurs are the first vertebrates that learned powered flight. Compared to most vertebrates, pterosaurs tended to have extremely large heads and extremely small legs relative to their torsos. Pterosaur wings were made from skin stretched from the body to an enormously elongated fourth finger. There are enough fossils preserving the soft tissue of pterosaurs to tell that the wings and body of pterosaurs probably had some kind of fur or protofeathers. All pterosaurs had a unique splint-like bone at the wrist called the pteroid, probably used to change the shape of the leading edge of the wing. Pterosaurs ranged in size from that of a sparrow to that of a small airplane.

Despite having a very different wing structure, pterosaurs are convergent with birds on many features. They had bones with very thin walls (presumably for lightness). They had very rigidified ribcages, and there is evidence in the bones for air sacs. Presumably these features could have allowed for an efficient one-way respiration system as in birds. Their brains tended to be large and globular, like a bird's, and not elongated like a typical reptile's. All these point to a life as agile fliers requiring large amounts of energy. The downside from our point of view is that their hollow bones are very fragile and end up crushed as fossils.

Classically pterosaurs are divided into two types: rhamphorhynchoids (named for Rhamphorhynchus) and pterodactyloids (named for Pterodactylus). Rhamphorhynchoids lived from the Late Triassic until the Early Cretaceous. They generally were small and had large toothed heads on a short neck. They also had long tails with a rhomboid-shaped vane at the end. Pterodactyloids lived from the Middle Jurassic until the Late Cretaceous. They had large heads on long necks, but no tails. Many of them were toothless.

I recently became aware of a group of Jurassic pterosaurs known from Europe and Asia called the anurognathids (named for the genus Anurognathus —"no tail jaw"). About 12 species have been defined. These are unusual because they have the short necks of rhamphorynchoids but (usually) no tail like pterodactyloids. Most notably, they also have skulls wider than they are long, whereas almost all other pterosaurs have long skulls.

Wei et al. (2021) describe a new anurognathid which they name *Sinomacrops bondei* ("large eyes from China"). The specimen is from the Jurassic Tiaojishan Formation of China. The body and head together would be about 5 inches long. Resolution is limited because the specimen is crushed. The tail vertebrae are not preserved, but there appears to be the impression in the matrix so the tail is at least 2 inches long. Some patches of integument are preserved. The face is short and there is one slender curved tooth preserved. Since the skull bones are not fused, this might be a juvenile. Phylogenetic analysis shows Sinomacrops is very similar to another anurognathid genus Batrachonathus.

Most of the paper deals with the relationship of anurognathids to each other and to other pterosaurs, most particularly whether anurognathids are more closely related to rhamphorynchoids or pterodactyloids. Previous work on this topic has produced contradictory conclusions, so it is likely there is not yet enough information to say for sure. This paper suggests anurognathids are a basal form of the group of pterosaurs called monofenestratans, which are thought to be stem pterydactyloids.

The possible lifestyle of Sinomacrops is not discussed in the paper. The popular press has noted a resemblance of the face of Sinomacrops to that of the "Porgs", a fictional egg-shaped sea-dwelling bird-like creature from the Starwars movie "The Last Jedi" (although to me the faces of Porgs seem more cat-like than bird-like). Anurognathids remind of a real living bird, the frogmouth. This is an Asian/Pacific nocturnal bird with large eyes, and a very short beak with a very wide gape for catching insects on the wing. Of course, many types of bats with short faces hunt insects at night in the same way, although they rely more on sonar than eyesight. Nocturnal insect hunting seems an appealing suggestion for the lifestyle of anurognathids.

Sources:

Wei, X.; Pegas, R.V.; Shen, C.; Guo, Y.; Ma, W.; Sun, D.; Zhou, X.
"*Sinomacrops bondei*, a new anurognathic pterosaur from the Jurassic of China and comments on the group."
PeerJ 2021, DOI 10.7717/peerj.11161.

Billion-Year-Old Holozoan from Scotland?

Bob Sheridan January 14, 2021

One very persistent topic in the paleo literature since from the late 1990's to the early 2010's has been the identity of the "Doushantuo embryos" from the Late Precambrian (~600 Myr) of China. These fossils are found in phosphate nodules. Fossils in such nodules are studied with an optical microscope after the nodule is sliced into thin sections. The "embryos" appear to be small (0.1-0.2 mm) clusters with anywhere from a handful to thousands of "cells." The cells may or may not be roughly the same size, and, depending on the state of preservation, the cluster may or may not be surrounded by a membrane with a characteristic texture. The original idea was that these represent embryos of "metazoans", i.e. multicellular animals of modern phyla. There are no fossils of adults in the Precambrian, but we would expect metazoans to exist that long ago based on a number of lines of reasoning. However, a lot of things seem inconsistent with these fossils being embryos:

1. The "cells" are very large, much larger than most cells in modern animals.
2. Embryos with thousands of cells should have formed blastulas or gastrulas already, not stayed as a undifferentiated cluster.
3. The embryos are much more common as fossils than you'd expect since the early stages of embryos do not last very long.
4. We never see later stages of these embryos.

Alternative explanations to the embryo hypothesis have been proposed. One is that they are clusters of giant sulfur bacteria. This seems unlikely because these the cells seem to have organized nuclei and bacteria don't. Another explanation is that they are adult holozoans. Holozoans are eucaryotes (excluding fungi) that form colonies of the same cell type, but cells of that type are also found living as single-celled organisms. The algae Volvox, which is a hollow sphere built from many Euglena-like protozoa, is an example. Holozoan colonies may be a solid sphere, in which case they are called a "stereoblast", or hollow sphere, in which case they are called a "cyst".

A paper by Strother et al. (2021) describes fossils in phosphate nodules from the Diabaig Formation in Scotland. The Formation is approximately 1 billion years old. These fossils have two forms. One is a sphere about 40 micrometers in diameter that is packed with uniform globular cells about 2.5 uM micrometers diameter surrounded by a layer of sausage-shaped cells about 1.5 micrometers in diameter and 5 micrometers long. The second form is very similar except that it is missing the sausage-shaped cells on the outside, and there is more than one type of cell of in the sphere. (Both are smaller by a factor of ~5 than the Doushantuo embryos.) The lack of space between cells in either form suggests that the cells do not have rigid cell walls, and thus are not likely to be affiliated with plants.

The authors suggested that both forms of fossils represent a single organism called *Bicellum brasieri* ("two cells" and after paleontologist Martin Brasier). The suggestion is that one type of cell in the second form migrates to the outside and forms the layer of sausage-shaped cells. Thus, the first form is the mature one. The authors feel that Bicellum is a holozoan, and this would be by far the oldest fossil example (almost twice as old as the Doushantuo "embryos"), and it indicates that very early holozoans had more than one type of cell.

The authors mention a theory that cells aggregate into layers because different cell types support different strengths of cell-cell adhesion, so, for example cells that stick together more strongly would be in the center of cell clusters and cells that stick together less strongly would form an outer layer.

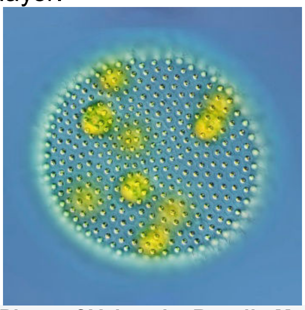


Photo of Volvox by Rogelio Moreno

Since spheres of animals cells would look similar no matter whether the creatures were related, it is just as easy to imagine the two forms described here are two different types of holozoans in the same environment as it is to imagine they are different life-stages of one holozoan.

Sources:
Strother, P.K.; Brasier, M.D.; Wacey, D.; Timpe, L.; Saunders, M.; 3 and Wellman, C.H.
"A possible billion-year-old holozoan with differentiated multicellularity."
Current Biol. 2021, 31,1-8.

Digging Mammilomorphs

Bob Sheridan April 10, 2021

Mao et al. (2021) describe two nearly complete specimens from the Early Cretaceous Jehol Formation of China. One they give the name *Fossimanus sinensis* ("digging hand from China"). This animal would have been about 16 inches long including the tail. Fossimanus is considered a tritylodontid, an advance synapsid, but not quite a true mammal. This is the first known tritylodontid from Jehol. They also describe a new animal *Jueconodon cheni* ("digging tooth"). This animal would have been about 10 inches long including the tail. Jueconodon, is considered a eutriconodontan, a true mammal that existed before the split of placentals and marsupials. Other eutriconodontans are known from Jehol.

The authors note that these two animals independently converged on adaptations for a fossorial lifestyle, i.e. they are specialized for “scratch digging”. The modern analog would be the mole. The most obvious features are very broad hands and short fingers with claws, attached to a very robust radius/ulna and humerus. The hindlimbs are small and the tails very short. The trunk of both animals is very long; this is due to having more thoracic vertebrae than normal for most mammals. They also have triangular heads and small eyes.

The authors speculate about the changes in HOX genes that control the number of vertebrae and note that plasticity in this aspect is evident early in the evolution of mammals. This further goes against the historical idea that Mesozoic mammals were boring and unspecialized.

Sources:
Mao, F.; Zhang, C.; Liu, C.; Meng, J.
"Fossoriality and evolutionary development in two Cretaceous mammaliamorphs"
Nature 2021, 593, 577-582.

Neandertal Footprints in Spain

Bob Sheridan April 16, 2021

Human trackways are fairly rare in the fossil record, but are unmistakable because the shape of human footprints is unique. Mayoral et al. (2021) report a set of human footprints near the southern coast of Spain. This is called the Matalascanas site, named after the beach-side resort in the area. The sediments in which the tracks are found are dated to approximately 106,000 years. Since no humans except Neandertals are known to inhabit Europe at that time, these are probably Neandertal tracks. The environment where the footprints were formed appears to be near a salty pond or tidal pool, as indicated by the remains of microbial mats and salt evaporates in the substrate, plus the fact that the substrate is very sandy.

There are a total of 87 footprints spread over an area of >500 square meters. These were recorded in 3D by photogrammetry using a camera on a drone, and most measurements were done on the virtual model of the site. These authors compiled the length and width of the footprints, although in some cases the footprints were not complete enough to do both. A few tracks include toe marks. The footprints are more or less consistent with other footprints assigned to Neandertals known from four other sites. The footprints are scattered in space and are pointed in more than one direction, so it is clear some purpose other than travel in a straight line was involved. However, the orientation of the trackways is more or less perpendicular to the shore of the pond.

Since there are still living humans, it is easy to find the statistical relationship between footprint length and the height of the human who made it. Also, there is a good relationship between height and age. We expect Neandertals to approximate these relationships closely, and indeed Neandertal skeletons support this expectation. The footprints at Matalascanas indicate a height range of 104 to 188 cm, and can be divided into three age ranges: 7 from children < 10 years old; 15 from adolescents (10-18 years old) and 9 from adults (>18years). All the footprints may be accounted for by as few as three individuals, although it cannot be ruled out that there were others of the same age. In this case, children outnumbered adults, which is not the case at other sites.

A reasonable assumption is that the Neandertals were hunting for birds, fish, or shellfish. This is the first unambiguous indication Neandertals inhabited a coastal environment, and also the oldest unambiguous Neandertal footprints in the world.

Sources:
Mayoral, E.; Diaz-Martinez, I.; Duveau, J.; Santos, A.; Ramirez, A.R.; Morales, J.A.; Morales, L.A.; Diaz-Delgado, R.
“Tracking late Pleistocene Neandertals on the Iberian coast.”
Scientific Reports 2021, 11: 4103.

Three Stories of *Tyrannosaurus rex*

Bob Sheridan April 23, 2021

Since Tyrannosaurus is everyone's favorite dinosaur, scientific publications concerning it get a great deal of popular press, even when the "news" is not especially surprising or the conclusions drawn are not particularly robust.

One of the most frequently mentioned stories in the popular press in the last few weeks concerns the publication of Marshall et al. (2021), where the authors estimate the total number of *Tyrannosaurus rex* that existed and from this the probability of any one individual being fossilized. To estimate such things, one needs to know, among other things:

1. The population density of Tyrannosaurus (individuals per square kilometer).
2. The range of Tyrannosaurus in square kilometers.
3. The total time Tyrannosaurus existed as a species.
4. The length of a generation.
5. The number of known fossil specimens.

Tyrannosaurus is a fairly well known dinosaur. For instance, we have nearly complete growth series and know how big they got and how long they lived. On the other hand, there are limits to our knowledge for any fossil animal. For example the range of a fossil species and the total time it existed are apt to be underestimates, since not all fossils have been found. Values of items above are not a single number, but a distribution, typically a bell-shaped curve. Uncertainty in the value is expressed as an average and one standard deviation around the mean, for example the mass of an adult T. rex is 5200 +/- 850 kg. Alternatively, one can use a confidence interval, for example, the true mass of an adult T. rex is within the range 3700 to 6900 kg with 95% confidence. This is how I will express things in the next paragraph because that is the way the authors express it. The important thing to realize in regard to this paper is that combining two numbers, each with some uncertainty, makes the final number more uncertain than the individual numbers.

What makes this paper novel is the application of a rule from 1981 "Damuth's Law" that links the population density of living mammals with their mass. Certainly, we see that mice are very common and elephants much less common. Among mammals, carnivores are much less common than herbivores. Animals with slower metabolism are more abundant than animals with higher metabolism because they can get by with less food. The authors make the assumption that T. rex (a carnivore) has a metabolism halfway between a varanid lizard and a lion, plus use a good estimate of its mass, to get from Damuth's Law a density of 0.00058 to 0.14 adult T. rexes per square kilometer. ("Two individuals in the area the size of Washington D.C." is how it is put.) Given a guess of the range at 1.42 to 3.18 million square kilometers over North America, this gives an estimate of 1,300 to 328,000 individuals living at any one time. Over the lifetime of this species (1.3 to 3.5 million years) and a generation time of 17 to 20 years, there would be anywhere between 140 million to 42 billion individuals. If there are 32 known adult specimens, the fossilization rate is 1 in 16,000 to 1 in 260,000.

For the past few weeks I have been seeing headlines like "2.5 billion T. rex lived on Earth." That is, the popular press quotes the average for the total number, but ignores the fact that the range of possible values is so big (a factor if 300!) as to make the estimate nearly meaningless. The biggest source of uncertainty, strangely, is not our knowledge about fossil animals, but from Darmuth's Law. For example there is a factor of 150 variation among carnivore abundance vs. mass among mammals. (One thing not mentioned in the discussion of Darmuth's Law is whether one is considering social or solitary mammals; certainly tigers would have a lower density than lions; this could be relevant to T. rex as seen in the second story.) One has to admire the attempt to make these calculations, but I am not inclined to believe the numbers.

I am reminded of the Drake Equation, a seven-term equation which is meant to estimate the number of extraterrestrial civilizations in our galaxy that we might currently communicate via radio. Some terms we know every well (the fraction of stars with planets: we now know of thousands of exoplanets, so this number is around 0.5-1.0) and some we have no clue (the fraction of life-bearing planets that will develop intelligent life: Earth is the only example, so no way to guess). Depending on what numbers you plug in, there are anywhere from <1 to millions of civilizations—a big uncertainty.

For the second story, we consider the idea that T. rex is a social dinosaur. There are many examples of monospecific bone beds for dinosaurs, where tens or hundreds of skeletons are found buried together. Centrosaurus, Allosaurus, and Coelophysis are examples. **Cont"d**

Aggregation of a single species could mean the dinosaurs moved in large packs and the whole pack was killed in a single event. It could also mean solitary animals were killed at about the same time, but their bodies were washed into a common grave. In some cases, it could mean that solitary individuals fell into the same trap over a long period of time (for example, as in a tar pit).

Titus et al. (2021) describe a Late Cretaceous (~76 Myr) site in southern Utah called the “Rainbows and Unicorn Quarry” (RUQ). The formation is generally sandstone and mudstone, and preserves a habitat that was wet and subtropical. It contains fossils of plant stems, charcoal, turtles, shells, fish, etc. These fossils are mostly fragmentary. The key fossils of interest here are probably from tyrannosaurids, although one ornithomimid being present cannot be totally excluded. The minimum number of individuals that could account for all the fragments is 4 and these fall in four size classes. The authors compare the fragments to the known skeleton of Lythronax and Teratophoneous, which are tyrannosaurids that lived in Utah at that that time. These tyrannosaurs are in the size range of 20-26 feet. This would make the individuals range from juveniles to adults (6-20 years old). The count distribution of skeletal elements is not far from that for complete skeletons, and the authors suggest that the individuals were complete when buried and were not transported far after death. However, there is some common orientation of the bodies, which might suggest the bodies may have been pushed by current. On the one hand, fracturing of the bones suggests they may have been exposed for a while before burial. On the other hand, there is no evidence for scavenging on the bones.

The authors consider many possible scenarios to explain why four tyrannosaurids are found together. There are other known bone beds of tyrannosaurids like Albertosaurus and Daspletosaurus. RUQ probably represents transport of gregarious individual into an oxbow lake by a flood, much like the scenario assigned to the Dry Island site (Albertosaurus). Isolated individuals falling into a common trap over a long period of time seems unlikely.

The popular press has made much of this paper, suggesting that Tyrannosaurus hunted in packs. First, it cannot be eliminated that these were solitary individuals that got washed into a common grave. Second, these animals are not Tyrannosaurus, but an earlier, smaller genus of tyrannosaurid, which might have had a different lifestyle. Third, this is not a novel finding. Daspletosaurus is closer in time and size to Tyrannosaurus than the tyrannosaurids in this paper, and a mass Daspletosaurus grave has been known for many years. There was a separate suggestion that Tyrannosaurus itself might be social based on the fact that the Sue specimen was found near a subadult and juvenile.

Now, to the third topic. Thanks to the arguments from the Dinosaur Renaissance in the 1980s the popular idea is that large theropod dinosaurs could run very fast. You probably remember the quoted speed of 32 mph for T. rex from “Jurassic Park”. Many mechanical simulations using various approaches and various assumptions have challenged this idea. The expected top speed for T. rex by today’s thinking is 10 meters per second (20 mph) or less. However, there is a great deal of extrapolation involved in these calculations; there are no elephant-sized bipeds around now to which we can make a comparison. There are dinosaur trackways of at least middle-sized theropods, but almost all of these represent a slow walk.

van Bijlert et al. (2021) estimate the walking speed of T. rex using an assumption about “natural frequency”. For walking, in one part of the stride, energy is stored in muscles and ligaments, and this energy is released in the later part of the stride. It is assumed that the usual walking speed is that at which the energy storage is maximal. If you imagine the energy storage system as a spring, the stride would be most energy efficient if the frequency of the steps matched the “natural frequency” of the spring. Imagine taking a spring, compressing it, and then letting it go. It would vibrate at its natural frequency, which would depend mostly on the mass and “stiffness” of the spring. The stiffness is the force needed to compress the spring by a given distance.

These authors imagine that the “spring” for a theropod dinosaur is in its tail, which is connected to the legs by caudofemoralis muscle. They simulated the tail as five stiff segments connected by a rotational spring (something like a watchspring for those who remember mechanical watches). The tail can vibrate only vertically. The authors need to estimate the mass of the tail segments, the zero-energy angle between the segments and the stiffness of the springs, which can be estimated by known ligament strengths from living animals. The result is a simulated tail frequency of 0.66 per second or 1.5 steps per second, and, given the stride length of T. rex, about, a speed of 1.3 meters per second (~3 mph). **Cont’d**

Using a slightly different estimate of the mass or length of the tail does not change the result significantly. The results were somewhat more sensitive to the assumptions about ligament stiffness. The authors claim that "natural frequency" theory correctly predicts walking speed in some mammals, but, of course, in those mammals the "springs" are in the legs, not the tail. One can easily point out issues of over-simplification with these calculations, the most obvious of which are that only the tail stores energy, and the only force on the tail is from ligaments (i.e. not muscles). The authors would counter that these are the only assumptions that would allow a calculation of this type.

The authors point out that there no trackways (only isolated footprints) of Tyrannosaurus to check the estimated speed from "natural frequency" against the estimated speed from footprint spacing. However, it should be possible to do similar calculations for dinosaurs for which there are trackways (for example assuming the trackway for "Eubrontes" belongs to Dilophosaurus). I am disappointed this was not done in this paper.

Sources:

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Science 2021, 32, 284-287.

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Earth's Earliest Collective Behavior

Bob Sheridan April 15, 2021

"Collective behavior" is the name given to any type of interaction between individuals of the same species. A paper from two years ago, which I only recently found out about, describes what it claims is the earliest known example. Vannier et al. (2019) describe a dozen linear clusters of trilobites from the Fezouata Shale from Morocco. This dates from the Early Ordovician (~480 Myr.). The substrate they are walking on appears to be siltstone. Clusters can have anywhere between 3 and 22 trilobites of the genus Ampyx, which is the most common trilobite in that formation.

Ampyx is a fairly unusual trilobite. It has a very short thorax, so that the shape of its body (head shield, thorax, and tail) is a short oval. It has three very long spines extending from its head shield. There is a forward-pointing spine about one and a half body-lengths long. Each cheek has a spine that curls backwards and ends more than one and a half body-lengths rearward of the tail. This is a small trilobite; the body length is only about 1.5 inches. Also, Ampyx has no eyes.

In all described clusters, almost all trilobites are nearly complete and articulated. The individuals appear to be about the same size, and are facing within 90 degrees in the same direction. Their bodies form a single line, although they are not all evenly spaced; sometimes one individual can seem to be on top of others. The authors want to establish this single-file walk as deliberate behavior, and therefore rule out other explanations. The fact that the individuals are all similarly oriented rules out accidental accumulation of bodies in the same place by a strong current. Plus, the substrate is not disturbed. If they were all walking up-current to some attractant they probably would not be in single file but spread out in a fan pattern. There is no trace of food that would account for all of them congregating in one place.

The suggestion of the authors is that Ampyx is carrying out some collective migratory or mating behavior. One modern analogy is with the seasonal migratory "conga-lines" formed by spiny lobsters. One can think of many more social behaviors among extant arthropods. Since Ampyx is blind, the individuals probably are using the spines of the trilobites ahead and behind to keep oriented. In two clusters there is a different, more conventional-looking trilobite, Asaphellus, in the line. It is not clear whether those are joining in the behavior or just got in the way. The authors claim that collective behavior shows a neural complexity that one might not necessarily expect so early in history. However, it seems to me that if today's arthropods have complex social behavior, their early cousins could too.

It is something of a mystery how the preservation occurred. Large numbers of individuals are frozen in place, perfectly oriented and perfectly articulated, which would imply they were completely buried after death. On the other hand, it is hard to imagine an event big enough to would bury them without leaving signs of a disturbance. One possibility is that they died from some local cause, for example anoxia, and were buried slowly.

Sources:

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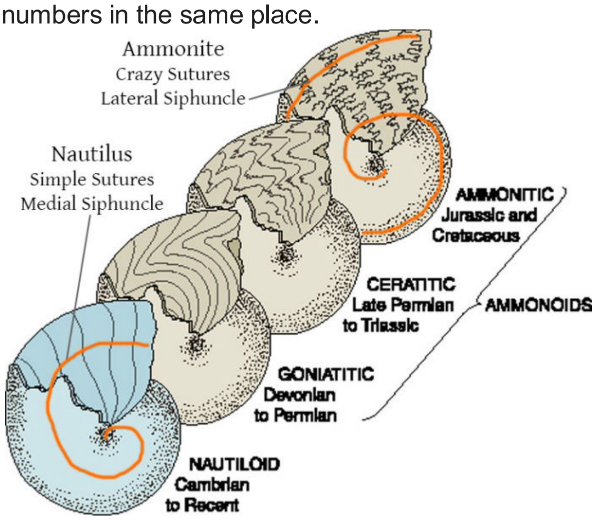
Why Are the Sutures of Ammonites So Complex

Bob Sheridan April 14, 2021

“Ammonites” and “ammonoids” are basically synonyms. These are common fossil mollusks thought to be related to today’s octopus, squid, and cuttlefish (i.e. cephalopods). They existed from the Late Silurian to the end of the Cretaceous. The fossil is usually a spiral shell (or conch) in the same plane. (Not all ammonites were tightly spiraled or spiraled at all.) These fossils have been appreciated for thousands of years. Pliny the elder called them “horns of Ammon” because it reminded him of the Egyptian god Amun who is depicted as wearing ram’s horns, and the original name “ammonite” means “Amun’s stones.” Parts of ammonites other than the shell are hardly ever preserved; ammonites are usually restored in appearance as something like the living Nautilus: a squid with its pointed end stuffed into Nautilus-like shell. However, although the Nautilus shell superficially resembles the ammonite shell, these animals are not particularly closely related as mollusks. Also the Nautilus tends to be solitary, but ammonites are thought to be very social, since fossils of one species are found in great numbers in the same place.



Both the Nautilus and ammonites have shells divided by “septa” into progressively larger chambers. The largest chamber is the one occupied by the living animal. As the animals grow, they add new shell material around the open end of the shell, move their bodies further out, and then close off the previously-occupied chamber. Unoccupied chambers are emptied of water and provide boyancy. A fleshy tube, the siphuncle, passes through all the septa, and is thought to control bouyancy by moving water into and out of the chambers via osmosis. In the Nautilus, the siphuncle pierces the center of the septum; in ammonites it is close to the shell wall.

The following discussion is easier if you imaging the ammonite shell is uncoiled so it looks like a very long cone. The place where the septum meets the outer shell is called the “suture”. If you imagine the septum is a flat or somewhat convex (with the convexity pointing to the apex of the cone), as it is in the Nautilus, the perimeter of the suture is a circle or oval. As seen from the side, the perimeter appears as a line. In most ammonites, the septum is ruffled at the edges, so the suture line appears wavy. The sutures are easy to see in fossils if the outer shell is worn away. Ammonites are divided into types based on the complexity of the suture line: goniatitic, ceratitic, and ammonitic. In ammonitic ammonites (which tend to be found later, i.e. in the Jurassic and Cretaceous), the suture line is very complex, nearly fractal, i.e. small wiggles on larger wiggles, on even larger wiggles. What selection pressure caused this great complexity in suture shapes? There is a lot of literature on this question. I will discuss two papers I came across recently.

Among the original ideas is that the complexity strengthens the shell, such that the shell could better resist the pressure difference between the surrounding water and the hollow space in the shell. Having a stronger shell would allow ammonites to dive deeper. A recent paper by Lemanis (2020) attempted to test this idea through simulation, specifically finite-element analysis. Finite-element analysis is a computational technique used in engineering to estimate local stresses in a structure of arbitrary shape made out of a specific type of material, and subject to specified forces. For example, it could point out which part of a bridge is most likely to fail because the stresses there are highest. In the ammonite study, Lamanis simulated cylinders and septa with varying wall thicknesses, septum spacing, septum thickness, and septum complexity (given various fractal formulas). A simulated force was applied against the outside of the cylinder to mimic water pressure. What is being measured is the resulting stresses on the septum or the shell wall under that force. Presumably, if a particular design resists collapse better, the local stresses should be less. In all cases, the most stressed points of the structures are near the sutures. However, the overall result is that increased complexity in the suture reduces stress in the shell wall, but increases it in the septum. The author concludes that overall strength against collapse is not helped by complexity. **Cont’d**

This is consistent with a lack of correlation in the fossil record between suture complexity and the type of environment (e.g. deep sea) where ammonites are found.

Peterman et al. (2021) tested an alternative idea, that increasing complexity of the septum helps water move into the empty chambers, hence more easily controlling buoyancy. These authors used 3D printing to generate physical models of hollow cylinders or chambers with septa of various complexities. The septa were designed using fractal formulas or copied from real ammonites. The authors dunked the models in water, poured the water out, and then measured how much water was retained. The models could be coated with a hydrophilic (water-loving), hydrophobic (water-hating) paint, or just left alone. This is relevant because nautilus shells have a hydrophilic coating. The result is that, for a given cylinder size, septa with more complexity retain more water, and a hydrophilic coating makes the effect much larger. The effect is noticeable only for the ammonitic patterns. The amount of water retained is not necessarily correlated with total surface area of the model.

That water is retained on a complex surface not surprising. Sponges, or other complex shapes, will retain water where a flat surface will not, due to surface tension, as long as water is not repelled from the surface. While the exact relationship of water retention to buoyancy is not necessarily straightforward, the argument made here is that better water retention in the chambers allows them to be more easily filled. The overall effect would be that the ammonites with complex septa would be somewhat less buoyant. One then has to ask the following questions: Is the weight of retained water enough to make an appreciable difference in buoyancy? Since the complexity of the septum is fixed, how does the ammonite become less buoyant?

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Scientific Reports 2021,11: 8055.

Earliest Unambiguous Fungus

Bob Sheridan June 9, 2019

Based on molecular clocks we would expect fungi to be a very ancient group (originating a billion years ago?) and preservable as microfossils. Several possible examples have been found in Precambrian sediments, but interpretation of these is ambiguous. Until now, the oldest unambiguous fungus fossils are from the Rhynie chert from ~410 Myr. A new paper from Loron et al. (2019) pushes the oldest fungus fossil much further back.

Loron et al. describe fossils in shale from the Grassy Bay Formation in Northwest Canada, which is dated to 1.0 billion years. The fossils are separated from the shale by dissolving the rock in acid. The remaining residue is studied by optical microscopy, scanning electron microscopy, Raman spectroscopy, and FTIR spectroscopy. The fossils consist of filaments (10-35 micrometers long) and spheres (33-80 micrometers in diameter). The arrangement of spheres on stalks, and right angle joins of filaments to other filaments is characteristic of fungi.

Modern fungus cell-walls are made of chitin, a long-chain polysaccharide, which is also seen in arthropod cuticles. The FTIR spectrum of the microfossils resemble the spectra of modern alpha-chitin and chitosan (a degradation product of chitin), confirming their identity.

Sources:

Loron, C.C.; Francois, C.; Rainbird, R.H.; Turner, E.C.; Borensztajn, S.
"Early fungi from the Proterozoic era in arctic Canada."
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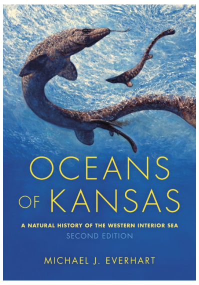

The 2nd Edition of *Oceans of Kansas – A Natural History of the Western Interior Sea* from Indiana University Press. The digital version is available from Amazon. The second edition is updated with new information on fossil discoveries and additional background on the history of paleontology in Kansas. The book has 427 pages, over 200 color photos of fossils by the author .

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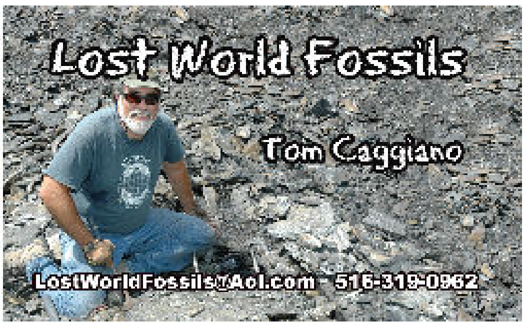

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